

# Plant Biomass Leaching for Nutrient Recovery in Closed Loop Systems Project

Center Innovation Fund: KSC CIF Program | Space Technology Mission Directorate (STMD)



## ABSTRACT

Plants will be important for food and O<sub>2</sub> production during long term human habitation in space. Recycling of nutrients (e.g., from waste materials) could reduce the resupply costs of fertilizers for growing these plants.

Work at NASA's Kennedy Space Center has shown that ion exchange resins can extract fertilizer (plant essential nutrients) from human waste water, after which the residual brine could be treated with electrodialysis to recover more water and produce high value chemicals (e.g., acids and bases). In habitats with significant plant production, inedible biomass becomes a major source of solid waste. To "close the loop" we also need to recover useful nutrients and fertilizer from inedible biomass.

We are investigating different approaches to retrieve nutrients from inedible plant biomass, including physical leaching with water, processing the biomass in bioreactors, changing the pH of leaching processing, and / or conducting multiple leaches of biomass residues.

## ANTICIPATED BENEFITS

### To NASA funded missions:

Recovering plant nutrients and allowing closed loop plant (and food) production helps reduce dependency on resupply from earth while saving on launch costs for manned presence in space.

Habitation beyond low earth orbit will require some form of closed loop plant/food growth, and recycling nutrients from inedible plant wastes will reduce consumables and resupply. The resulting nutrient stream can then be purified and added back to plant systems using technology previously developed through KSC IR&TD.



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## Management Team

### Project Manager:

- Nancy Zeitlin

### Principal Investigator:

- Raymond Wheeler

### Co-Investigator:

- Griffin Lunn

## Technology Areas

### Primary Technology Area:

Human Health, Life Support, and Habitation Systems (TA 6)  
└ Human Exploration  
Destination Systems (TA 7)

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This technology has possible commercial use in reducing fertilizer consumption and more sustainable crop production. Because the nutrients are recovered from plant biomass, fertilizer generated in this fashion could potentially qualify for "organic" labeling.

## **To NASA unfunded & planned missions:**

Reduce consumables and mass penalties for growing food on long duration missions.

## **To other government agencies:**

Provide "organic" approaches for generating plant fertilizers (e.g., USDA)

## **To the commercial space industry:**

Improve potential for in situ food production systems for commercial space vehicles or habitats.

## **To the nation:**

Provide possible approaches for achieving more sustainable agriculture in controlled environments.

## **DETAILED DESCRIPTION**

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Bioregenerative technologies, such as growing plants, could contribute to human life support on future space missions and are currently being tested as a source of fresh food production on the International Space Station (ISS). By harnessing photosynthesis, plants could produce oxygen and scrub CO<sub>2</sub> from space craft or habitats, and if crops are selected, the plants could also provide a regenerable source of food. As with any life support technologies, growing plants will have costs, including power for electric lighting, water pumps, etc., mass for the growing equipment and water for start-up, and various consumables such as some sensors, pumps, lamps, and fertilizer salts to provide their nutrients. Anything that can reduce these costs, including reductions in consumables like fertilizer will increase the potential for using plants.

Plants require the following elements for growth (listed in an approximate order of mass need): N, K, Ca, Mg, P, S, Fe, Mn, B, Zn, Cu, and Mo. Studies from the 1990s at Kennedy Space Center and universities (Rutgers, Purdue, and Tuskegee) showed that many of these nutrients could be recycled from inedible leaves and stems by processing them in various ways, such as using continuously stirred tank reactors (CSTRs). Depending on the plant species and processing time, over 50% of the nutrients could be recycled to grow subsequent crops. N and K seemed to be very soluble (and recoverable), while Fe, Ca, and P were not recovered as well (for example, see

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papers by R.F. Strayer and colleagues). Loading rates of these reactors was in the range of 15 to 30 g dried inedible biomass per liter of water, and the reactors all operated in a gravity dependent mode. For space applications, the volumes of water would likely have to be reduced, and the fluids handling adapted for a given gravity setting. In addition, improving the recovery of Fe, Ca, and P would help further close the mass loop and reduce costs for growing the plants.

The current testing at Kennedy Space Center is looking at different approaches to improve the total nutrient recovery from plant biomass. This includes using reduced water volumes (increased solid loading rates), and tentatively using gravity independent approaches for retrieving nutrients from inedible plant biomass. We are focusing on inedible biomass from peppers and tomatoes, as compared to earlier studies in the 1990s that used crops like wheat and potato. Among the treatments will be multiple water leaches for biomass, reducing the pH of the leaching process, combining these steps with bioreactors processing, and ultimately gathering sufficient leachate or effluent to reconstitute a nutrient solution for growing subsequent plantings of peppers and tomatoes. Our hope is that the reduced pH will improve recovery of Fe, Ca, and P. We will also test fresh, ground (blended) biomass for treatment instead of the traditionally used, dried biomass, which require energy for drying.

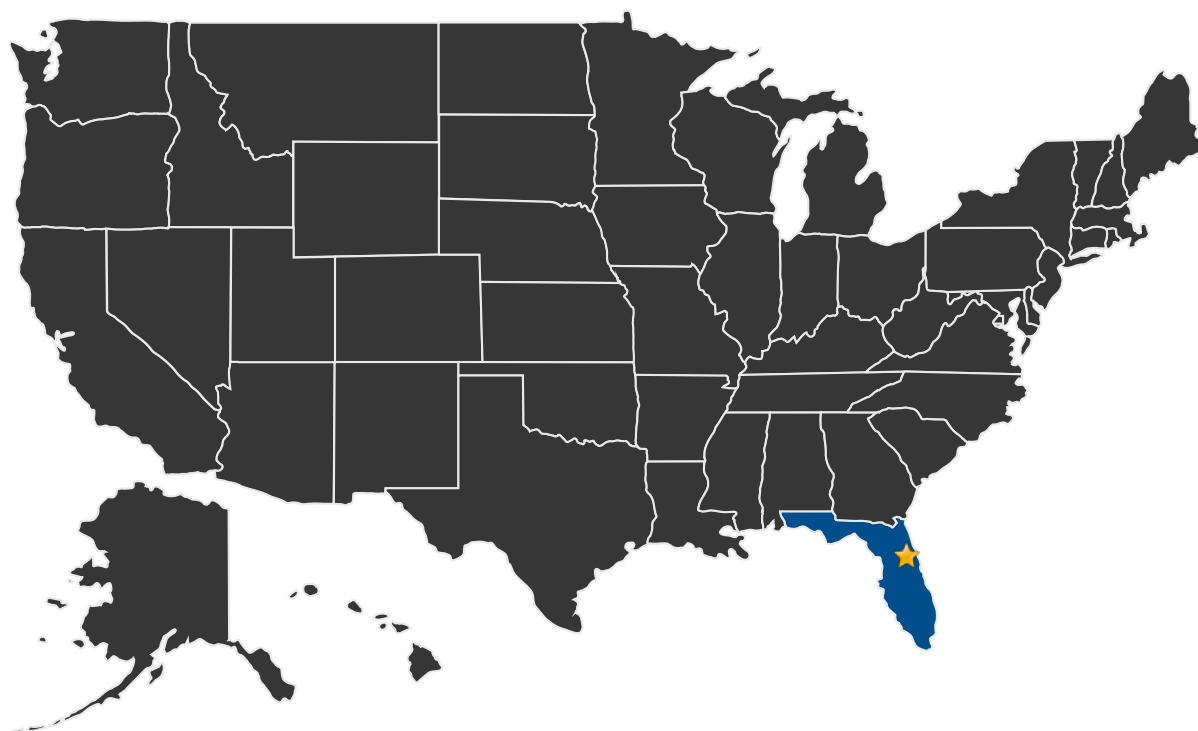
Active Project (2015 - 2016)

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## U.S. LOCATIONS WORKING ON THIS PROJECT



■ U.S. States With Work      ★ **Lead Center:**  
Kennedy Space Center

## DETAILS FOR TECHNOLOGY 1

### Technology Title

Environmental Control and Life Support Systems

### Technology Description

This technology is categorized as a hardware component or part for ground scientific research or analysis

Approach for recycling essential nutrients (elements) to support plant growth on extended

**TechPort**

For more information visit [techport.nasa.gov](http://techport.nasa.gov)

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Some NASA technology projects are smaller (for example SBIR/STTR, NIAC and Center Innovation Fund), and will have less content than other, larger projects. Newly created projects may not yet have detailed project information.

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missions.

## Capabilities Provided

Provide essential nutrients (fertilizer) for growing plants for life support contributions.

## Potential Applications

The approach could be implemented on ISS if expanded plant growth systems are configured for near continuous operations (e.g., continuous fresh food production). Similar applications could be considered for transit and surface missions.

## Performance Metrics

Metric	Unit	Quantity
Nutrient recovery	%	60%